AISC Steel Construction Manual

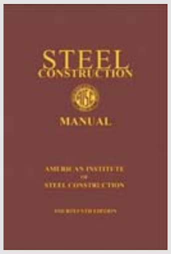
Overview

The AISC Steel Construction Manual

- In the past there were two AISC design manuals:
  - ASD 9th Edition (green book) – for Allowable Stress Design (ASD)
  - LRFD 3rd Edition (blue book) – for Load and Resistance Factor Design (LRFD)
  - The previous AISC Manual, the 13th Edition (black book) first incorporated both ASD and LRFD
- The current manual is the 14th Edition (red book)
  - Includes both ASD and LRFD provisions

Organization

- The Manual includes:
  - Part 1: Dimensional Information
  - Part 2: Material Properties
  - Parts 3-6: Design Aids for Members
  - Parts 7-15: Design Aids for Connections
  - Part 16: Specifications and Codes
  - Part 17: Miscellaneous Information



The AISC Specification

- AISC specifications are adopted by reference in the building code
  - International Building Code (IBC)
  - California Building Code (CBC)
- The AISC specification covered in this class is formally called AISC 360-10
  - Referenced by IBC 2012 / CBC 2013.

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- AISC specifications are adopted by reference in the building code (California Building Code)
- The AISC specification covered in this class is formally called AISC 360-10, referenced by IBC 2012 / CBC 2013.
- AISC specifications are developed by consensus, based on research by academics and experience of practitioners
- AISC specifications are minimum standards for safe design. Judgment & experience are needed to recognize when it is necessary to go beyond "code minimum"
- The Structural Engineer of Record has final (and personal) responsibility for the design

Organization

- Focus of class is on:
  - Requirements of the specification
  - Use of the design aids for efficient design
  - Application of spec and design aids on assignments and exams
- Note that the specification is code!
  - Other parts of manual considered design aids for efficient design using the specification

AISC Design Provisions

Overview

Design Provisions

- Allowable Strength Design (ASD)
  - Legacy approach to design
  - Applied loads are not factored up
  - Strength of steel material is reduced by a factor of safety to restrict required strength to allowable levels
- Load and Resistance Factor Design (LRFD)
  - Applied loads are factored up
  - Capacity of steel material is reduced by a reduction factor

Nominal Capacity is Common

- ASD:
  - Required Strength at Unfactored Load Combinations = R_a
  - Allowable Strength= R_n/Ω
- LRFD
  - Required Strength at Factored Load Combinations = R_u
  - Design Strength = ϕR_n

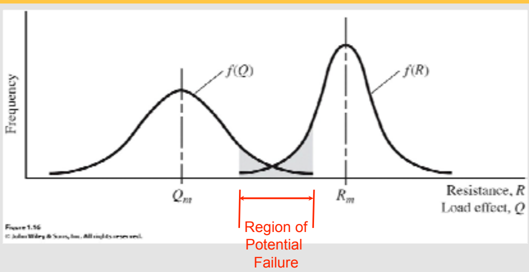
ALWAYS WORKING FROM SAME NOMINAL CAPACITY!

Structural Safety

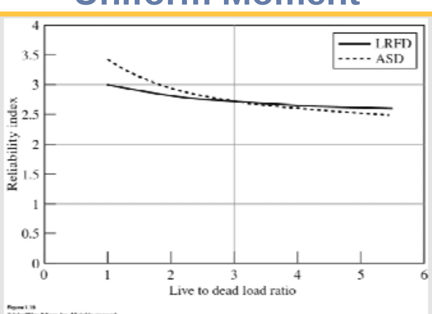
Structural members must always be designed to carry some reserve capacity to account for overload and under strength, due to:

- Dimensional tolerances
  - Fabrication
  - Construction
- Material strength variations
- Limits of simplified design equations
- Uncertainty in applied loads

Probability Distribution of Load and Resistance



Reliability of WF Beam with Uniform Moment



Structural Safety

- The magnitude of a “factor of safety” (or “reliability index”) is a function of economics versus probability of occurrence
- Zero probability of failure is uneconomical
- No margin of safety is illogical and ethically unacceptable

LRFD Load Combinations

- Load Combinations per AISC pg 2-10

Load and Resistance Factor Design

For LRFD, the required strength is determined from the following factored combinations,[1] which are based on ASCE/SEI 7 Section 2.3:

1. $1.4D$ (2-3a)
2. $1.2D + 1.6L + 0.5(L_r \text{ or } S \text{ or } R)$ (2-3b)
3. $1.2D + 1.6(L_r \text{ or } S \text{ or } R) + (0.5L \text{ or } 0.5W)$ (2-3c)
4. $1.2D + 1.0W + 0.5L + 0.5(L_r \text{ or } S \text{ or } R)$ (2-3d)
5. $1.2D + 1.0E + 0.5L + 0.2S$ (2-3e)
6. $0.9D + 1.0W$ (2-3f)
7. $0.9D + 1.0E$ (2-3g)

ASD Load Combinations

- Load Combinations per AISC pg 2-11

Allowable Strength Design

For ASD, the required strength is determined from the following combinations, which are also based on ASCE/SEI 7 Section 2.4:

1. D (2-4a)
2. $D + L$ (2-4b)
3. $D + (L_r \text{ or } S \text{ or } R)$ (2-4c)
4. $D + 0.75L + 0.75(L_r \text{ or } S \text{ or } R)$ (2-4d)
5. $D + (0.6W \text{ or } 0.7E)$ (2-4e)

6a. $D + 0.75L + 0.75(0.6W) + 0.75(L_r \text{ or } S \text{ or } R)$ (2-4f)

6b. $D + 0.75L + 0.75(0.7E) + 0.75S$ (2-4g)

7. $0.6D + 0.6W$ (2-4h)
8. $0.6D + 0.7E$ (2-4i)

Load Combinations

- Where:

D = dead load
L = live load due to occupancy
L_r = roof live load
S = snow load
R = nominal load due to initial rainwater or ice exclusive of the ponding contribution
W = wind load
E = earthquake load

LRFD Resistance Factors & ASD Safety Factors

- Per AISC pg 2-12

$\phi = 0.90$ for limit states involving yielding
$\phi = 0.75$ for limit states involving rupture

$\Omega = 1.67$ for limit states involving yielding
$\Omega = 2.00$ for limit states involving rupture

The general relationship between the safety factor, Ω, and the resistance factor, ϕ, is

$$\Omega = \frac{1.5}{\phi} \quad (2\text{–}5)$$

LRFD Design

3. Design for Strength Using Load and Resistance Factor Design (LRFD)

Design according to the provisions for *load and resistance factor design* (LRFD) satisfies the requirements of this Specification when the *design strength* of each *structural component* equals or exceeds the *required strength* determined on the basis of the *LRFD load combinations*. All provisions of this Specification, except for those in Section B3.4, shall apply.

Design shall be performed in accordance with Equation B3-1:

$$R_u \le \phi R_n \quad \text{(B3-1)}$$

where
R_u = required strength using LRFD load combinations
R_n = *nominal strength*, specified in Chapters B through K
ϕ = *resistance factor*, specified in Chapters B through K
ϕR_n = design strength

Spec: B3.3

ASD Design

4. Design for Strength Using Allowable Strength Design (ASD)

Design according to the provisions for *allowable strength design (ASD)* satisfies the requirements of this Specification when the *allowable strength* of each *structural component* equals or exceeds the *required strength* determined on the basis of the *ASD load combinations*. All provisions of this Specification, except those of Section B3.3, shall apply.

Design shall be performed in accordance with Equation B3-2:

$$R_a \le R_n/\Omega \tag{B3-2}$$

where

R_a = required strength using ASD load combinations
R_n = *nominal strength*, specified in Chapters B through K
Ω = *safety factor*, specified in Chapters B through K
R_n/Ω = allowable strength

Spec: B3.4

Serviceability

- In addition to having strength for the imposed loads, the structure must consider *serviceability*

L1. GENERAL PROVISIONS

Serviceability is a state in which the function of a building, its appearance, maintainability, durability and comfort of its occupants are preserved under normal usage. Limiting values of structural behavior for serviceability (such as maximum deflections and accelerations) shall be chosen with due regard to the intended function of the structure. Serviceability shall be evaluated using appropriate *load combinations* for the *serviceability limit states* identified.

Spec: L1

Serviceability

- Serviceability limit states include:
  - Deflection
  - Vibration
  - Wind-Induced Motion
  - Thermal Expansion/Contraction
  - Connection Slip

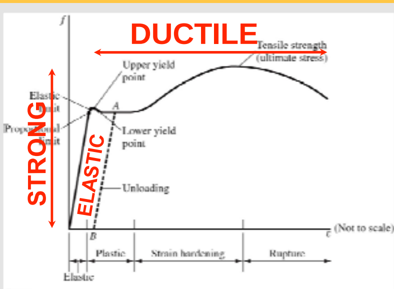
Steel Building Materials

Structural Steel Material

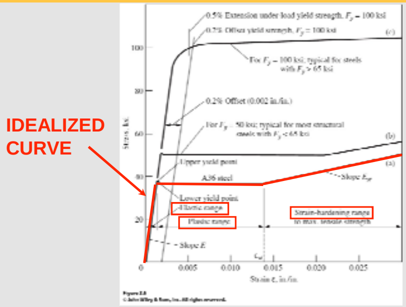
Advantages
- High Strength
- Uniformity
- Elasticity
- Ductility
- Permanence
- Toughness
- Simple to connect

Disadvantages
- Maintenance
- Fireproofing
- Susceptibility to Buckling
- Fatigue
- Brittle Fracture

Advantages of Steel



Typical Stress-Strain Curves



Basic Relationships and Quantities

- E=29,000 KSI (Elastic Modulus)
- E_{st}=900 KSI (Elastic Modulus, Strain Hardening)
- μ ≈ 0.3 (Poisson's Ratio)
- G= E/(2(1+ μ)) ≈11,000 KSI (Shear Modulus)

Ductility

- The amount of permanent strain up to the point of fracture.
- A measure of the ability of the material to continue to perform load-carrying function without post-yield failure.
- Contrasted to brittle behavior.
- Also defined by Δ_u/Δ_y

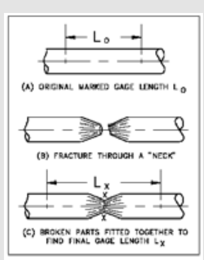
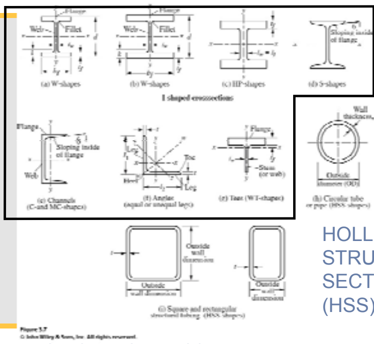


Figure 6 Measuring Elongation After Fracture

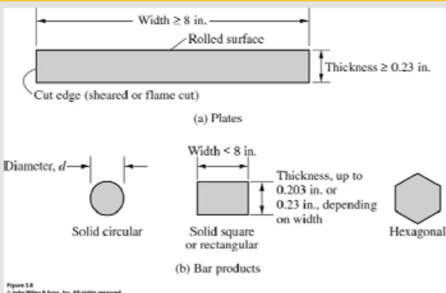
Standard Shapes

ASTM A6 ROLLED SHAPES



HOLLOW STRUCTURAL SECTIONS (HSS)

Plate and Bar

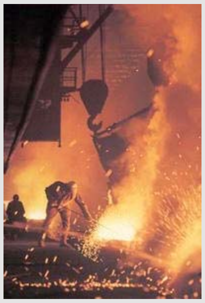


Why are there so many shapes?

- Different steel shapes are efficient to resist certain applied loads:
  - Tension: rods or angles
  - Compression: tubes or "boxy" wide flange sections
  - Bending: deep wide flange sections
  - Combined Bending and Axial: heavier wide flange sections or tubes
  - Torsion: tubes

Structural Steel Chemistry

- 98% Iron
- 0% to 2% Carbon
- Other elements
  - Manganese
  - Silicon
  - Copper
  - Etc.



How Steel Shapes are Made

- Produced in a Mill
  - Molten steel created primarily from scrap metal
  - Solid chunks of steel created (ingots)
  - Hot-Rolled into shapes in the mill (60’-75’ lengths)

How Steel Shapes are Made

Most Common Materials

Table 2-4
Applicable ASTM Specifications for Various Structural Shapes

Steel Type	ASTM Designation		F_y Min. Yield Stress (ksi)	F_u Tensile Stress[a] (ksi)	Applicable Shape Series: W	M	S	HP	C	MC	L	HSS: Rect.	HSS: Round	Pipe
Carbon	A36		36	58-80[b]	▒	■	■	▒	■	■	■			
	A53 Gr. B		35	60										■
	A500	Gr. B	42	58									■	
			46	58								■		
		Gr. C	46	62									▒	
			50	62								▒		
	A501	Gr. A	36	58								▒	▒	
		Gr. B	50	70								▒	▒	
	A529[c]	Gr. 50	50	65-100	▒	▒	▒	▒	▒	▒	▒			
		Gr. 55	55	70-100	▒	▒	▒	▒	▒	▒	▒			
High-Strength Low-Alloy	A572	Gr. 42	42	60	▒	▒	▒	▒	▒	▒	▒			
		Gr. 50	50	65[d]	▒	▒	▒	■	▒	▒	▒			
		Gr. 55	55	70	▒	▒	▒	▒	▒	▒	▒			
		Gr. 60[e]	60	75	▒	▒	▒	▒	▒	▒	▒			
		Gr. 65[e]	65	80	▒	▒	▒	▒	▒	▒	▒			
	A618[f]	Gr. I & II	50[g]	70[g]								▒	▒	
		Gr. III	50	65								▒	▒	
	A913	50	50[h]	60[h]	▒	▒	▒	▒	▒	▒	▒			
		60	60	75	▒	▒	▒	▒	▒	▒	▒			
		65	65	80	▒	▒	▒	▒	▒	▒	▒			
		70	70	90	▒	▒	▒	▒	▒	▒	▒			
	A992		50	65[i]	■	▒	▒	▒	▒	▒	▒			
Corrosion Resistant High-Strength Low-Alloy	A242		42[j]	63[j]	▒									
			46[k]	67[k]	▒			▒						
			50[l]	70[l]	▒	▒	▒	▒	▒	▒	▒			
	A588		50	70	▒	▒	▒	▒	▒	▒	▒			
	A847		50	70								▒	▒	

■ = Preferred material specification
▒ = Other applicable material specification, the availability of which should be confirmed prior to specification
□ = Material specification does not apply

Most Common Materials

Table 2-5
Applicable ASTM Specifications for Plates and Bars

Steel Type	ASTM Designation		F_y Min. Yield Stress (ksi)	F_u Tensile Stress[a] (ksi)	Plates and Bars: to 0.75 incl.	over 0.75 to 1.25	over 1.25 to 1.5	over 1.5 to 2 incl.	over 2 to 2.5 incl.	over 2.5 to 4 incl.	over 4 to 5 incl.	over 5 to 6 incl.	over 6 to 8 incl.	over 8
Carbon	A36		32	58-80										■
			36	58-80	■	■	■	■	■	■	■	■	■	
	A529	Gr. 50	50	70-100	▒	▒ b	▒ b	▒ b	▒ b					
		Gr. 55	55	70-100	▒	▒ b	▒ b							
High-Strength Low-Alloy	A572	Gr. 42	42	60	▒	▒	▒	▒	▒	▒	▒	▒		
		Gr. 50	50	65	▒	▒	▒	▒	▒	▒				
		Gr. 55	55	70	▒	▒	▒	▒						
		Gr. 60	60	75	▒	▒								
		Gr. 65	65	80	▒	▒								
Corrosion Resistant High-Strength Low-Alloy	A242		42	63				▒	▒	▒				
			46	67		▒	▒							
			50	70	▒									
	A588		42	63								▒	▒	
			46	67							▒			
			50	70	▒	▒	▒	▒	▒	▒				
Quenched and Tempered Alloy	A514[c]		90	100-130						▒	▒	▒		
			100	110-130	▒	▒	▒	▒	▒					
Quenched and Tempered Low-Alloy	A852[c]		70	90-110	▒	▒	▒	▒	▒	▒				

■ = Preferred material specification
▒ = Other applicable material specification, the availability of which should be confirmed prior to specification
□ = Material specification does not apply

[a] Minimum unless a range is shown.
[b] Applicable to bars only above 1-in. thickness.
[c] Available as plates only.